Let's torque about measurement technology

The need to monitor torque in rotating shafts has been around for at least 100 years. Here, **Tony Ingham** of Sensor Technology looks back at the original methods and shows how today's state of the art evolved

Engineers use rotating shafts to transmit power. In Victorian times it was sufficient to know that this was happening, but it soon became important to know how much power was actually being provided. The very first power measurements were probably taken by noting the time to lift a set amount of water a given height, and using one of those new-fangled slide rules for the calculations!

This developed over the years into a need for constant readings, so that the actual power being transmitted at any moment in time was known. This was the birth of modern torque measurement, and since then the basic techniques have been steadily improved for accuracy and usability.

Taking accurate measurements

Today, accurate torque measurement is vital for optimising the performance of a great range of machines; and direct and continuous torque measurement is generally preferred over the indirect methods of previous generations. This is done by measuring the amount a shaft twists in use, using a transducer to convert a (tiny) angular measurement into an electrical signal.

One of the early ways to do this with a significant degree of accuracy was to use a strain gauge bonded directly to the shaft. Early strain gauges tended to be wires or foils, which stretched under torque, changing their electrical resistance. Today, diffused semiconductor and thin film options are also available.

If the shaft only rotates through a fixed angle, the strain gauge can be directly connected to the signal conditioning electronics. This, however, is not possible on freely rotating shafts, hence the development of the slip ring, and more recently the inductive coupling.

Slip rings use simple brush contacts. While these are low cost and offer reliability in low speed, low load applications, they are less suitable for many of today's high-performance applications. Additionally, slip rings will wear, creating dust, and can generate significant amounts of electrical noise that may corrupt signal measurements.

It was inevitable, therefore, that alternatives to slip rings would be developed. One example is to use a rotary transformer to inductively couple the strain gauge to the electronics. This works on the same principle as a conventional transformer, but with either the primary or secondary coils rotating. Electrical noise, however, can be a problem, and the bulky equipment can impact system dynamics.

Developments

Around 25 years ago it became apparent that driven machinery would soon require a less cumbersome approach to torque measurement – so options using radio telemetry were looked at. This system uses a stationary antenna to induce power into a loop antenna mounted on the rotating shaft to power the strain gauge transmitter, while a stationary coil placed nearby picks up the signal and feeds it to a decoder.

A radio telemetry system has the benefits of being non-contact, low maintenance and reliable. Having been used in many applications, some of them demanding in the extreme, it is now accepted as the preferred method of torque measurement in many situations.

Alongside signal transmission, development engineers also looked at options other than foils for the actual torque measurement. Optical sensors provided one solution. Sectioned discs mounted at either end of the shaft move relative to each other as the shaft twists under torque and change the effective aperture through which a light beam passes. Unaffected by electromagnetic interference or noise, the optical technique reached a zenith of popularity in the 1980s and 1990s, and is still used in low torque and high bandwidth applications.

In a similar arrangement, proximity and displacement sensors have been used to measure the angular displacement between toothed wheels at either end of the shaft.

A recent development, born out of Formula 1, has been magneto elastic materials that become increasingly magnetic when torque is applied. Not commonly used yet, this is tipped for future popularity.

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SAW technology

In the early 1990s Sensor Technology began to investigate the use of surface acoustic waves (SAWs) for torque measurement. SAWs are also called Rayleigh waves, because they were discovered by Lord Rayleigh when he was researching earthquakes in the 1880s.

SAW sensors are quartz devices, which change their resonant frequency under applied torque. As these are passive devices, they require no power supply on the shaft. They can also be interrogated using an RF link. This creates a totally non-contact system that has the benefits of being bi-directional, with fast mechanical and electrical responses. There are no brushes or complex electronics, and no need for phase measurement or magnetic measurement technologies.

SAW transducers have become popular, and are now widely used in test rigs, liquid-handling applications, mixers, nuclear applications, aerospace component testing, the food industry, pharmaceuticals, and materials handling.

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